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Performance of sounding retrievals from AIRS, GOES10, MODIS and HIRS Radiances during Mini-Barca campaign – June 2008

Simone Sievert da Costa [1]
Jurandir Ventura Rodrigues [1]
Weber Andrade Gonçalves [1]
Rodrigo Augusto Ferreira de Souza [2]

[1] Instituto Nacional de Pesquisas Espaciais - INPE
Caixa Postal 01 – 12630000 - Cachoeira Paulista - SP, Brasil
{simone.sievert, jurandir.rodrigues,weber.goncalves}@cptec.inpe.br

[2] Universidade do Estado do Amazonas - UEA
Manaus - AM, Brasil
souzaraf@gmail.com

Abstract. This work aims to present some preliminary results on the evaluation of clear sky sounding retrievals operationally processed at DSA-CPTEC/INPE. Radiances are from AIRS, GOES10, MODIS and HIRS sounder sensors. The inverse solution is solved using five different processing packets (i.e. IMAPP, IAPP, GOES, MODIS, NASA-AIRS). The vertical sounding profiles are evaluated through the comparison with radiosonde from the MiniBarca campaign over the Amazon region. The statistical analyses of the temperature profiles are based on bias, root mean square error and correlation coefficient. Biases and RMSE changes are function of the retrieval scheme and sensor spectral resolution. NASA and IMAPP algorithms applied to AIRS sensors tend to represent the temperature inversion observed close to surface, while other retrieval seems to neglect it. AIRS and GOES10 and MODIS (AQUA and TERRA) present high temperature correlation (i.e. R > 0.8) with radiosonde data at lower levels (below 900 mbar) while HIRS present lowest correlation of 0.6. The statistical analyses of the humidity for GOES10 and NOAA18 - the only sensors used at present moment to infer moisture at DSA-CPTEC/INPE - shows that the mean error is lower than ±0.5 g/kg for GOES10 and is almost twice as bigger for HIRS-NOAA18. Overall, the retrieved temperature and moisture profiles are in reasonable good agreement with radiosondes. However, the results indicate stronger moisture biases than temperature biases. Further analyses must be carried out on the sources errors, such as initial conditions, radiances biases and cloud mask.

Key-Words: sounding retrieval, temperature and humidity profiles, sondagens, inferência de perfis termodinâmicos.

1. Introduction

Knowledge of temperature and humidity field distribution are essential for a wide variety of applications, such as meteorological weather forecast, data assimilation and nowcasting. In other to provide temperature and humidity fields, retrieval schemes base on the radiances observed by satellite have been developed and freely distributed to the meteorological centers. In general, sounding retrieval are based on modifying the surface and atmospheric temperature/moisture profiles in a manner such that brightness temperatures calculated agree with those observed from satellite, within some uncertainty estimate.

The Satellite and Environmental System Division (DSA) of Center for Weather Forecast and Climatic Studies – (CPTEC/INPE) receives data from different sensors and employ operationally six different sounding retrieval inversion schemes in near real time (Table 1): i) **GOES10-sounder** developed at CIMSS is based on a nonlinear physical retrieval algorithm. The retrieval begins with a first-guess temperature and water vapor profile that is obtained from a space-time interpolation of fields provided by CPTEC forecast model. This algorithm uses a nonlinear Newtonian iterative method to find the optimal solution to the nonlinear

inverse of the radiative transfer equation. ii) **IAPP -** International ATOVS Processing Package, which operates on NOAA18, retrieves the atmospheric parameters in 4 steps: cloud detection and removal; bias adjustment; regression retrieval; and nonlinear iterative physical retrieval. iii) **IMAPP** - International MODIS/AIRS Processing Package is derived from the operational Earth Observing System processing software developed at NASA and Jet Propulsion Laboratory. iv) **NASA inversion model** - is a physically-based inversion procedure for operational sounding retrieval which combined AIRS radiance measurements from microwave and infrared sounder. The importance to infer atmospheric variables from several different satellites is that can be provided extensive and comprehensive information about atmospheric components and its processes with high spatial and temporal resolution. In this context, the present study aims to analyze the performance of temperature and humidity (sounding) inferred at DSA-CPTEC/INPE.

Table 1 – Satellite sensor and operational retrieval scheme used in the vertical profiles at DSA-CPTEC/INPE.

Technical Feature	Sounding Retrieval Sensors and Processing algorithms					
satellite	GOES10	ATOVS NOAA18	TERRA	AQUA	AQUA	AQUA
sensor	GOES-Sounder	HIRS	MODIS	MODIS	AIRS	AIRS
Orbit	geostationary	polar	polar	polar	polar	polar
Product Spatial Resolution (km)	10	100	1	4	50	50
Satellite Overpass during Minibarca Campaign:	1 hour /sector (South America = 4 sector)	around 3:00, 5:00, 16:00 and 18:00 UTC	around 3:00,14:00 and 15:00 UTC	around 5:00 and 18:00 UTC	around 5:00 and 17:00 UTC	around 5:00 and 17:00 UTC
Inversion model scheme	Ma et al., 1999 algorithm	IAPP (Li et al., 2000)	IMAPP-MOD07 PGE03_v4.3	IMAPP-MOD07 PGE03_v4.4	IMAPP v5.2.1	NASA Susskind. (2003)
N. of levels retrieved	40	42	20	20	28/100	28
N. of channels in the retrieval	19 (18)	20	36 (11)	36	27	2378 (20)
First Guess	CPTEC Global Model T213L42	Regression	Regression	Regression	NCEP	Regression

2. Methodology and Data

Sounding retrievals via satellite were validated using the radiosonde from the mini-BARCA experimental campaign. The campaign, which was aimed to understand the Amazon region as a regional entity, occurred during 9 to 30th June 2008. Although this period corresponds to the ending of the raining season, various convective activities occurred. Around four atmospheric radiosondes were launched around daily at 00, 06, 12 e 18 UTC in five sites: Manaus-AM, Tabatinga-AM, Rio Branco-AC, Belém-PA and Carolina-MA. Figure 1 shows the location of the five sites over the Amazon Region. In this study was used the matched dataset containing radiosonde and satellite data within $1.0^{o.}$ (i.e. approximately 100 km) and also conditioned to clear sky based on the algorithms cloud mask. From approximately 500 radiosondes samples, only a reduced number was used in the comparison. Each retrieved sounding product have different sample size (Table 2) used in the error analyses, since each satellite present distinct time overpass. The sounding retrieval errors

were evaluated using the mean statistical values of bias (satellite minus radiosonde), root mean square error (RMSE) and correlation coefficient.

Figure 1 – Experimental sites of the Mini-Barca Campaign over Amazonas region: Manaus-AM (3.14°S 59.9°W), Tabatinga-AM (4.25°S 69.94°W), Rio Branco-AC (9.86°S 67.90°W), Belém-PA (1.47°S 48.46°W) and Carolina-MA(7.34°S 47.60°W).

Table 2 – Matched dataset containing radiosonde and satellite retrievals and the sample size used in the statistics analyses. Sample size is reduced because of cloud contamination.

Satellite - Sounder	Matched dataset	Sample size in the statistics
GOES10-sounder	244	80
NOAA18- HIRS	39	22
TERRA- MODIS	35	17
AQUA- MODIS	102	24
AQUA –AIRS (NASA)	114	30
AQUA AIRS (IMAPP)	83	34

3. Results

Figure 2 shows the vertical temperature (a) and humidity (b) profiles retrieved by different sensors and retrievals schemes for morning (06:00 UTC, Carolina) and night (18:00 UTC, Rio Branco) of 22 June 2008. Additionally, it presents the vertical profiles observed by radiosondes in the scope of Mini-Barca campaign. Visible and Infrared GOES10 image shows that 22 June was partially cloudy over Rio Branco at 6:00 UTC, clear sky over Carolina at 18:00 UTC.

The NASA and IMAPP algorithms applied to AIRS sensors tend to represent the majority of the temperature vertical structure at the surface, such as the temperature inversion, while other retrieval schemes seem to unresolved. This high performance by AIRS sounder is expected since it provides radiances in thousands of channels for single field of view, yielding to significant increase of information about gases absorption and emission, mainly close to surface.

Figure 3 (a) shows the statistical analyses of the temperature profiles based on bias, root mean square error and correlation coefficient. AIRS-IMAPP and AIRS-NASA seems disagree at lower levels close to the surface while they present same accuracy above the 850 mbar. AIRS presents a remarkable improvement when compared with other instruments, as mentioned before. AIRS- MAPP presents bias of +0.3 K while AIRS-NASA and HIBS-NOAA presents error of around -/+1.5 K. Both AIRS retrievals present RMSE of around 1 K over all levels. GOES10 retrieved algorithm has a good performance over all levels, the RMSE is around 1 K. GOES10 sounder present high correlation with radiosonde data at lower

levels (below 900 mbar), following by AIRS (IMAPP and NASA) and MODIS (AQUA and TERRA (i.e. R ~ 0.8), and HIRS (R~0.6). All retrievals temperature sounding show that the correlation coefficients are highest at surface, decrease with height and presents minimum around 780 mbar associated to highest bias. Further analyses must be done in order to understand this low performance of the algorithms in this level.

Figure 3 (b) shows the statistical analyses of the humidity only for GOES10 and NOAA18, since they are the only sensors used at present moment to infer moisture at DSA-CPTEC/INPE. The mixing ratio mean error (bias) is lower than ±0.5 g/kg for GOES10 retrieval and the RMSE is around 1g/kg, and the corresponding values for HIRS-NOAA18 are almost twice as bigger (i.e. vies around 1 g/kg and RMSE of about 2 g/kg). The correlation of between radiosondes and retrieved moisture is lower than those correlation found to temperature. This is because atmospheric moisture presents more variability than temperature. It is also more complicate to retrieve in atmospheric thermodynamic processes due to latent heat (Li et al., 2008). Gonçalves et al. (2008) shows GOES10 humidity retrieval improves considerable when the covariance matrix was update for the Amazon region.

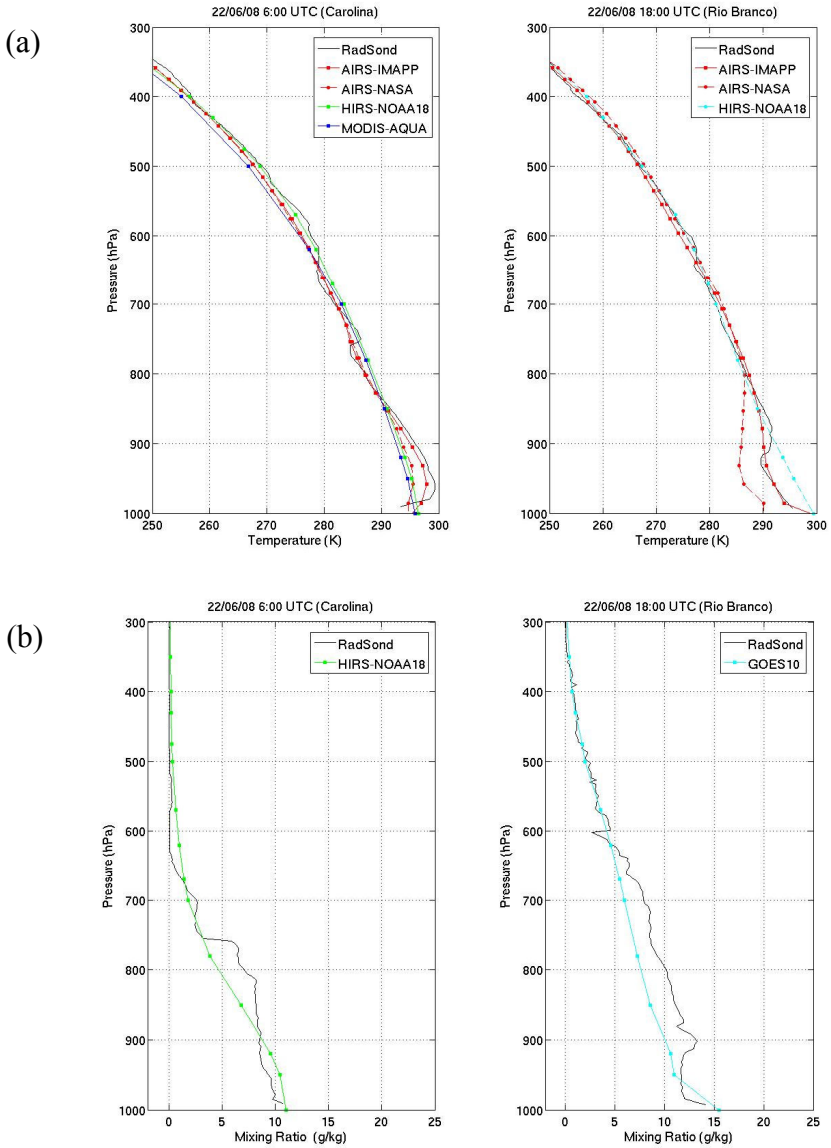

Figure 2 – Vertical profiles of temperature (a) and mixing ratio (b) retrieved for different sensors and algorithms compared with two radiosondes from MiniBarca campaign.

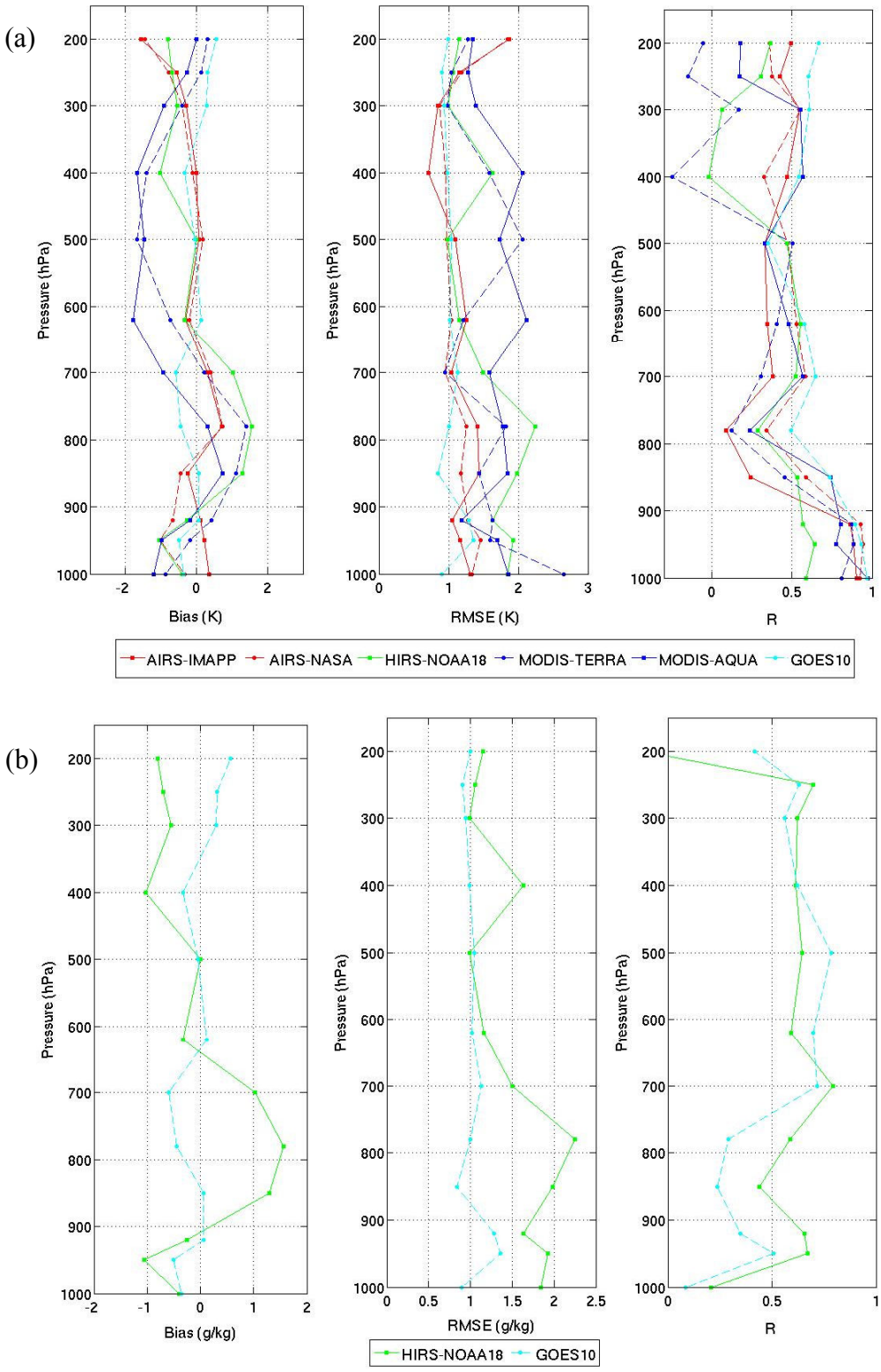

Figure 3 – Comparison of statistical analyses (Bias, RMSE and Correlation coefficient) for the retrieved (a) temperature (K) and (b) mixing ratio (g/kg) as function of pressure.

4. Conclusion and Future work

This paper has analyzed the performance of the retrieval sounding using at DSA/CPTEC-INPE. Overall, the retrieved temperature and moisture profiles are in reasonable good agreement with radiosondes. GOES10, AIRS-IMAPP and AIRS-NASA temperature retrievals present better agreement with radiosondes, mainly at the surface. The AIRS retrievals could even capture the main temperature characteristics such as inversion close to the surface. GOES10 retrieval scheme presents good performance for temperature sounding. Although, the errors in humidity are quite small for GOES10, the correlation between radiosonde and retrieval are low ($R<0.5$) between 700 and 1000 mbar. According to Gonçalves et al., 2008, the updated of the covariance matrix of GOES10 for the region over Amazon is essential for increase the retrieval scheme performance.

The differences between the retrieval and radiosonde data can be due differing measurement characteristics (point versus volumetric), error in radiosonde, discrepancies in space and time of retrieval as well errors associated to satellite retrieval and radiosonde. For instance, some studies showed the radiosonde errors are 0.5K for temperature and 10 % for humidity (Pratt, 1985; Wade, 1994; WMO, 1996). Another source of error is due to the surface uncertainties, such as surface elevation, emissivity and skin temperature. Future work will investigate these source errors in the retrieval processes.

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